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ARTICLES

N.I.A.B. VARIETY TRIALS

E. G. THOMPSON

Head of Crop Improvement Branch,
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During World War I, Lawrence Weaver, then an official of the Food Production Department, found that crop failures were occuring because farmers were unknowingly using seed of low germination. This so shocked him that he determined to ensure that it would be possible for the farmer to have his own seed tested and to be sure that any seed he purchased would also be of satisfactory quality. One or two private testing stations were in operation, but an Official Seed Testing Station was established in London in 1917, and later a Testing of Seed Order was made which came into force on January 1, 1918.

Weaver was, however, concerned not only with laboratory seed testing but with the need to " gather into one Institute the best men who were in touch with the problems of agricultural seed, whether research workers and other agricultural scientists, officials in close touch with seed problems, leaders of agricultural thought, practical farmers, seed growers and merchants, or corn merchants and millers". By January 1919 the National Institute of Agricultural Botany was established and the first council meeting held. It was an independent body receiving grants from the Development Commission but relying partially on its own resources and governed by the Council which was composed of men of the type described in the quotation.

The Institute was established with three main divisions: the Official Seed Testing Station, the Potato Station at Ormskirk where testing for wart disease had been developed, and a Crop Improvement and Administrative Branch designed to test and to market new crop varieties. A Seed Production Branch was added during World War II and the potato work, somewhat altered in character, was moved from Ormskirk to Cambridge where the other work was centred. At the present time it is the Crop Improvement and the Potato Branches which are particularly concerned, in co-operation with the N.A.A.S., in conducting field tests of new varieties.

Problems affecting Variety Trials

When this work first started one of the major problems was to sort out the genuinely new varieties from those new only in name. There was a time when 75 per cent of the varieties of potatoes offered for wart-disease testing were found to be old varieties under new names. The position was not quite as bad with cereals, but synonyms were quite common. In both crops the position has been completely altered by the work of committees set up to examine the varieties and to give publicity to any synonyms found. The Potato Synonym Committee, under the chairmanship of Dr. Salaman, pioneered this work and conducted a vigorous campaign from its inception in 1920. Public opinion in the seed trade has given both committees so much support that new synonyms in potatoes and cereals are now rare and, when they do occur, are usually accidental. There is, however, still some sorting out to be done in other crops.

The main problem in cereals at the present time is not the existence of synonyms, but the difficulty of testing adequately the very large numbers of genuine new varieties being produced, not only in Britain but in the countries of Northern Europe where the climate is fairly similar to our own.

The original plan for the preliminary testing was to place the new varieties in different parts of the country in field observation plots adjoining plots of a standard variety. New varieties which showed obvious defects, such as weakness of straw, susceptibility to disease, or visibly low yield, could be discarded and the rest placed in replicated yield trials. This system is still used to a small extent, but nowadays the plant breeder is perhaps less optimistic than his predecessors and he rarely releases varieties with serious visible defects. Observation must therefore be linked with some assessment of yield, since this is such an important feature for the grower. Furthermore, observation—even over the different regions of the country—cannot be relied upon to disclose disease resistance unless the testing is carried on for several seasons.

Introduction of Small-Scale Replicated Field Trials

In recent years the yield problem has been partially dealt with by carrying out small-scale replicated field trials of the new varieties for one or two years at Cambridge, while continuing to grow observation plots in other regions of the country. The trials are sown with a drill of normal pattern but only 4 ft. wide. Six replications are included in a randomized block arrangement and the plots each give about 1/100th acre for harvest. These plots can now be harvested with the special small combine, and it is intended that observation plots shall be almost completely replaced in the near future by four of these small-scale trials placed at centres in different areas of the country.

The difficulty of determining disease resistance is being met to some extent by the development of controlled inoculation in the glasshouse or in the field. This was shown to be necessary in the case of Yellow Rust of wheat; research had shown that there were several strains of Yellow Rust, which differed in their ability to attack any given variety of wheat. It is now possible to record separately in one or two seasons the resistance of a new variety of wheat to all the common strains of the rust. Inoculation with loose Smut is also carried out with wheat and barley varieties, but this is a longer process and field results are not obtained until twelve months after the inoculation. However, a rather tedious laboratory test will give much quicker results when necessary.

The development of specific tests for characters in new varieties is likely to increase, and already tests for Stem eelworm in oats are being applied and other tests are being investigated. While these controlled tests will never completely replace field observations, they may greatly help in the preliminary sorting of new varieties.

Primary Trials

When a variety has passed the test of the small-scale trials it is placed into the full-scale field trials, now commonly described as the primary trials because of the further series of trials arranged with the N.A.A.S. The primary trials are planned on a field scale large enough to be sown, cultivated and harvested with machinery used by the ordinary farmer. The officer in charge has always been instructed to follow the best accepted practice of his district in seed rates, cultivations and manuring, and in nearly every case the trial is placed in a field of the same cereal following the usual rotation of the farm. Thus, even when it is impossible to explain the results obtained, it is safe to advise growers that if they use a particular variety in the ordinary way they are likely to obtain the results shown in the trial. It is true that in the past year or so different rates of manuring have been applied to each trial, but this is extending rather than altering the older practice.

Primary trials are grown at some or all of about twenty centres. Thirteen of these are centres where the N.I.A.B. maintain a Regional Trials Officer and the farms are usually those of Universities, Colleges or County Farm Institutes. The N.A.A.S. also co-operates, and primary cereal trials are grown at five of the Experimental Husbandry Farms, while a few are grown on private farms supervised either by a N.A.A.S. officer or by a Regional Trials Officer of the N.I.A.B.

These N.A.A.S. centres provide other soil types or conditions to supplement those of the N.I.A.B. Regional Centres, and the varieties are thus tested in many different arable farming regions. The centres are located over the whole of England from Kent and Devonshire to Lancashire and Northumberland. There is a centre in Wales at the N.A.A.S. Experimental Farm at Trawscoed, near Aberystwyth, and another in Scotland on the farm of the East of Scotland College of Agriculture, near Edinburgh.

Ideally, each new variety which passes the test of the small-scale trials should be grown at all these centres, but the numbers have been too great to allow this and usually a new variety will be grown at six to eight centres chosen to vary the conditions as much as possible. It will normally continue at these same centres for three years.

The primary trial is a replicated one designed to give a reliable indication of yield, since this is of the greatest importance in all crops. In the oats trials, the yield of straw is recorded as well as the yield of grain, but difficulties of sampling for moisture content make the straw figures less accurate than those for grain. Yield alone, however, is not sufficient, and the quality of the produce must be tested.

Testing for Quality

It has been the consistent policy of the N.I.A.B. to seek the opinion of the users of any product concerning its quality. For instance, the quality of the wheat grown in the trials has been determined for many years by the Cereals Research Station of the Research Association of British Flour Millers. The station tests not only the milling character of the grain but also the suitability of flour made from it for bread-making or biscuit-making. Oats are also tested at this station, although the trials officers have always made a determination of the percentage of husk in the oat grain one of the most important quality points in oats.

The testing of barley quality presents great difficulty, since the minor variations in barley use are numerous and brewing, still an art, is less standardized than many industries. Nevertheless, valuable reports on quality are obtained regularly. The Institute of Brewing has co-operated with the N.I.A.B. for many years in the estimation of quality, and individual firms have carried out experimental maltings on samples drawn from the trials.

The Cereal Trials Advisory Committee

When the primary trial period is completed a comprehensive report is presented to the Cereal Trials Committee. This Committee of the Institute is composed of members with wide agricultural, consumer, or technical experience of cereals, but without breeding or commercial interest in any particular variety. If the report indicates that a new variety has shown superiority to varieties already on the Recommended List, the Committee will recommend to the Council of the Institute that it should be provisionally added to the list. A new variety will normally remain in this provisional category for three years during which time further information is obtained about its behaviour. A further report is then made to the Committee and the position reviewed. From time to time this Committee also recommends the removal from the list of varieties superseded by more recent additions.

Secondary Trials

It has already been stated that there is co-operation between the N.A.A.S. and the N.I.A.B. in the primary cereal trials, and there is even greater co-operation in primary trials of potatoes and vegetable crops. The great majority of N.A.A.S./N.I.A.B. cereal trials, however, are those described as the secondary series. This series is designed to test varieties which have already shown some promise in the primary trials and may in some cases have already been provisionally recommended.

The purposes of the secondary trials are threefold:

1. *To extend the trials of the more promising varieties into all the main arable areas.* This provides for testing under a wider range of conditions than those existing on well-farmed teaching or experimental farms. Differential responses to soil deficiencies of a minor element have been disclosed in secondary trials although they were not seen in the primary trials. Since the secondary trials are usually much more numerous than the primary trials they provide a greater opportunity of disclosing any marked regional suitability of the varieties.

2. *To provide evidence on which the "provisional" decisions of the Cereal Trials Advisory Committee can be confirmed or amended.* To fulfil this purpose the secondary trials should include all the provisionally recommended varieties; also those varieties on which the Cereal Trials Advisory Committee requested further evidence after normal primary trials were complete, before reaching a decision whether or not to "recommend".

3. *To demonstrate the promising new varieties to the farmers.* This is such an obvious use that little need be said about it except to draw attention to its limitations. More than nine-tenths of the new varieties prove to be no better than existing varieties for our conditions; but many of them fail only in yield, a feature which cannot be seen by inspection, nor proved by a single trial.

The examination of the trial results usually discloses a considerable variation in the behaviour of a variety between one trial and another in the same season, or between seasons at the same centre, for which no obvious explanations can be offered. This emphasizes the need for a definite series of trials placed in different areas and carried out for several seasons. It is, of course, only possible to combine for statistical treatment as a single trial series the results of separate trials containing exactly the same varieties. The larger the trial series, the more information it can provide. From this point of view the ideal arrangement is to have the same group of varieties in every secondary trial throughout the country. For this reason, special varieties in which there is strong

local interest should be additional varieties, and not substitutes for varieties in the series as a whole. It is only after an extensive trial series that there can be any hope of finding regional suitability unless it is very strongly developed.

When the secondary trials are completed the results will be reported to the Cereal Trials Committee, but a full report will also be written for publication. This report is written jointly by a N.A.A.S. officer and an officer of the N.I.A.B., and is published in the *N.I.A.B. Journal*. Before it is published the draft report is seen by all the Provincial Crop Husbandry Officers and if the results appear to justify it, a summary of the whole or part may be published on a Provincial basis.

Trials of other Crops

Cereals were a convenient choice to illustrate the trials organization of the N.I.A.B. but trials of many other crops are carried out in a similar way. Apart from the Cereal Trials Advisory Committee there are four other committees closely concerned with trial work :

The Potato Synonym and Trials Committee
The Root Trials Advisory Committee
The Vegetable Trials Advisory Committee
The Herbage Seeds Advisory Committee

The Cereals Committee deals also with pulse crops, and the Roots Committee deals with other fodder crops besides roots, so that the five committees between them cover nearly all the arable crops.

The work of the Cereals and Potato Committees has resulted in the production of lists of varieties which are definitely recommended. The root and vegetable crops are often open-pollinated crops in which strains may be important as well as varieties, and although definite recommendations have been made of sugar beet strains, there are some crops in which the work has not advanced to this stage and the reports are mainly descriptive.

The N.A.A.S. has co-operated in the work covered by all these committees, sometimes in the preliminary work of observation plots, as with rapes and kales and the extensive series of fodder beet plots, and at other times with replicated trials both primary and secondary. Sugar beet trials have not been included at more than one N.A.A.S. centre as the British Sugar Corporation co-operates closely with the N.I.A.B. and has an agricultural staff at each factory able to undertake considerable experimental work.

Variety trial work is not the only activity of the Potato and Crop Improvement Branches of the N.I.A.B. Potato Branch has the responsibility of producing and issuing to potato seed growers small quantities of virus-free tubers of the most widely grown varieties.

This involves work under glass at Cambridge and subsequent multiplication in Northern Ireland and Scotland, with testing for virus at all stages. The Crop Improvement Branch has the task of multiplying stocks of new varieties produced by the Cambridge Plant Breeding Institute and in some cases by the Welsh Plant Breeding Station. It is also responsible for the multiplication of stock seed produced by the Vegetable Research Station. This Branch thus fulfils one of the original purposes of the Institute—the trial and distribution of new varieties.

FIELD EXPERIMENTS ON PHOSPHATE FERTILIZERS

G. W. Cooke

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During the last war it seemed likely that there would be a scarcity of imported rock phosphate and of sulphuric acid (made here from imported pyrites or sulphur)—from which materials superphosphate is made. The Fertilizer Control of the Ministry of Supply therefore requested that alternatives to superphosphate should be developed and tested in field experiments. This was done between 1941 and 1946. A sudden world-wide shortage of sulphur in 1950 resulted in a further field investigation being initiated in 1951 by the Fertiliser Conference of the Agricultural Research Council to test phosphate fertilizers which either needed no sulphuric acid for their manufacture, or which economized in acid.

In both series of investigations the bulk of the field work was carried out by the Provincial Soil Chemists of the Ministry of Agriculture, by the staffs of the Colleges of Agriculture and the Macaulay Institute for Soil Research in Scotland, by the Chemical Research Division of the Northern Ireland Ministry of Agriculture, and by the staff of the Welsh Plant Breeding Station. The work was planned and co-ordinated in the Chemistry Department at Rothamsted. This paper gives a brief account of the more important results of these investigations (some 400 experiments) to which the local officers of the Advisory Services have contributed so much. Detailed results of the 1941-46 experiments have been published by Crowther and Cooke [1] ; a full account of the later work will also be published in due course.

Ground Rock Phosphates for Direct Application

When supplies of acid for superphosphate-making are restricted, an obvious alternative is to use ground rock phosphates where they are suitable. War-time experiments were made to test hard rock phosphates from Florida and Curaçao which were imported to replace the well-known soft North African types. Gafsa rock phosphate from North Africa was tested wherever possible in 1941-46, and it was also used in the 1951-53 experiments.

Swedes

Ground Florida rock phosphate tested in 1941 gave yields of swedes equal to those given by only one-quarter as much P_2O_5 supplied as superphosphate, and in experiments on reseeded grass it was also very inefficient. Florida phosphate was therefore not considered to be worth further testing. A hard rock phosphate from Curaçao in the Dutch West Indies behaved in much the same way as Gafsa phosphate. The average results of twenty-four experiments on swedes are given below.

Table 1

Average Yields of Swedes in 24 Field Experiments carried out in 1941-42 to test Rock Phosphates

Phosphate Tested	P_2O_5 applied	Yield of Swedes
	cwt. per acre	*tons per acre*
No phosphate	—	8.9
Superphosphate ...	0.5	17.4
	1.0	18.6
Rock phosphates		
Gafsa	1.0	18.0
Curaçao	1.0	18.0

The superphosphate yield response curve was plotted, and the dressings of P_2O_5 applied (as superphosphate) which would have been required to give yields equal to those given by the other phosphates tested were read off. These *equivalent superphosphate* dressings were expressed as percentages of the amount of P_2O_5 actually applied (as rock phosphate). *Percentage superphosphate equivalents* calculated in this way are used in this paper for most of the phosphate fertilizers tested as alternatives to superphosphate. The method is approximate but it is a drastic test of alternative phosphate fertilizers ; it cannot be used if the materials under test give markedly better yields than superphosphate or if the superphosphate response curve is flat. By dividing the experiments in Table 1 into a group where the soils were very acid (*p*H 5.5 or below) and a group on less acid soils (*p*H above 5.5),

the percentage superphosphate equivalents stated below were obtained. Rock phosphates were more efficient on very acid soils than on less acid soils.

Type of Soil	Number of Experiments	Percentage Superphosphate Equivalents	
		Gafsa	Curaçao
Very acid soils (*below* pH 5.6) ...	16	82	75
Less acid soils (*above* pH 5.5) ...	8	34	40

Swede experiments in 1945-46 and in 1951-53 using lower rates of dressing tested Gafsa rock phosphate. The results are summarized in Table 2 together with those of experiments on Morocco rock phosphate carried out in 1943-44. The 1951-53 experiments also tested dicalcium phosphate and silicophosphate which are discussed later in this paper, yield data being given here for convenience. Percentage superphosphate equivalents derived from the yields in Table 2 are given in Table 3.

Table 2

Average Yields of Swedes and Potatoes in Experiments testing Gafsa and Morocco Rock Phosphate, Dicalcium phosphate and Silicophosphate

Phosphate Tested	P_2O_5 applied	1943-44 Swedes (9 *experiments*)	1945-46 Swedes (6 *experiments*)
	cwt. per acre	*tons per acre*	*tons per acre*
No phosphate	—	10.1	6.9
Superphosphate	0.33	16.0	13.8
	0.66	17.6	16.3
Rock phosphate ...	0.5	15.6 (*as Morocco*)	13.5 (*as Gafsa*)
		1951-53 Swedes (35 *experiments*)	1951-53 Potatoes (34 *experiments*)
		tons per acre	*tons per acre*
No phosphate ...	—	12.0	9.4
Superphosphate	0.33	17.4	10.6
	0.66	19.6	11.1
Gafsa rock phosphate ...	0.5	18.2	10.1
Dicalcium phosphate ...	0.5	18.4	10.8
Silicophosphate ...	0.5	18.2	10.6

Table 3

Percentage Superphosphate Equivalents of Rock Phosphates derived from Swede Experiments grouped by Soil Reaction

Type of Soil	1943-44 (Morocco rock phosphate)	1945-46 (Gafsa rock phosphate)	1951-53 (Gafsa rock phosphate)
Very acid (*below* *p*H 5.6) ...	64 (5)	—	91 (10)
Acid (*p*H 5.6-6.5) ...	38 (4)	—	86 (22)
Neutral (*above* *p*H 6.5) ...	—	—	12 (3)
All soils	56 (9)	58 (6)*	86 (35)

*Five " very acid " and one " acid " soil.
Numbers of experiments are given in brackets.

For swedes, North African rock phosphates were, on average, between 60 and 90 per cent as efficient as superphosphate. In the earlier experiments, rock phosphates were most effective on very acid soils, but in the 1951-53 experiments Gafsa phosphate was nearly as efficient on the less acid soils as on the very acid ones. Swedes are now restricted to the north and west of the United Kingdom in areas where most of the soils are acid and rainfall is high; and for most swede crops ground rock phosphate could be used instead of superphosphate. The price per unit of P_2O_5 in rock phosphate is little more than one-third of the price of unit P_2O_5 in superphosphate (taking current subsidies into account). Further experiments on fodder crops like kale and on grass are in progress to see how far this very cheap material can replace more expensive fertilizers.

POTATOES

Rock phosphates were tested in a few war-time potato experiments and were much inferior to superphosphate, even on acid soils. Gafsa phosphate was compared with superphosphate in the 1951-53 potato experiments summarized in Table 2, and these yields were used to calculate the following percentage superphosphate equivalents :

Type of Soil	Number of Experiments	Percentage Superphosphate Equivalents
Very acid (*below* *p*H 5.6) ...	10	34
Acid (*p*H 5.6-6.5) ...	15	37
Neutral (*above* *p*H 6.5) ...	9	4
All soils	34	30

Gafsa phosphate was of very little value for potatoes grown on neutral soils. Even on acid soils it gave yields similar to those resulting from the application of only one-third as much phosphorus supplied as superphosphate. Rock phosphates and mixtures of rock phosphate with superphosphate should therefore not be recommended for potatoes.

Reseeded Grassland

Visual observations of experiments on very acid soils showed that finely ground rock phosphates gave the same degree of establishment and early growth of reseeded grass as only one-third as much phosphorus supplied as Bessemer basic slag. The more soluble phosphates such as basic slag or superphosphate should be used for establishing grassland. Current experiments are being made to investigate whether rock phosphates may be used to maintain growth of established pastures.

Mixtures of Rock Phosphate and Superphosphate

Mixtures of this kind, which have been sold in Northern Ireland under the name of " Semsol " were prepared and tested in the war-time experiments. The reaction between the components does not go further than neutralizing the free acid in superphosphate. " Semsol "-type phosphate was slightly more efficient than mineral phosphate for swedes, but even on acid soils it gave yields equal to those given by only two-thirds as much phosphorus applied as superphosphate. On acid soils " Semsol "-type phosphate produced yields of potatoes similar to those resulting from half as much phosphorus applied as superphosphate. Such mixtures have no advantages over equivalent amounts of straight mineral phosphate and superphosphate used correctly.

Silicophosphate

The Building Research Station of the Department of Scientific and Industrial Research investigated methods of sintering mineral phosphate with soda ash and sand to produce a readily available phosphate which was called " Silicophosphate". The products tested in both series of field experiments were fine powders ground so that practically all passed the 100 mesh sieve. They contained 30-33 per cent of total P_2O_5, of which nearly all was soluble in 2 per cent citric acid but none was soluble in water.

Swedes and Potatoes

In experiments carried out in 1942, silicophosphate was markedly superior to superphosphate for swedes. For potatoes, silicophosphate was only three-quarters as efficient as superphosphate.

Experiments on both crops in 1943-46 and in 1951-53 used the same rates of dressing. The results, which are comparable, are summarized in Table 4 by stating percentage superphosphate equivalents for silicophosphate and grouping the experiments by soil *p*H.

Table 4

Percentage Superphosphate Equivalents of Silicophosphate from Experiments on Swedes and Potatoes

Type of Soil	Percentage Superphosphate Equivalents	
1943-46 Experiments	Swedes	Potatoes
Very acid (*below p*H 5.5)	90 (10)	90 (8)
Acid (*p*H 5.6-6.5)	84 (12)	59 (10)
Neutral (*above p*H 6.5)	72 (7)	62 (7)
All soils	83 (29)	71 (25)
1951-53 Experiments		
Very acid (*below p*H 5.6)	90 (10)	92 (10)
Acid (*p*H 5.6-6.5)	84 (22)	56 (15)
Neutral (*above p*H 6.5)	52 (3)	30 (9)
All soils	86 (35)	65 (34)

Numbers of experiments are given in brackets.

On very acid soils, silicophosphate was practically as effective as superphosphate for both swedes and potatoes. On neutral soils, silicophosphate was only one-half to three-quarters as efficient as superphosphate for swedes, and for potatoes it was much inferior to superphosphate on both less acid and neutral soils.

Reseeded Grass

Experiments were carried out on reseeding of grassland on acid soils in the Welsh hills. Visual estimates of establishment and growth gave almost identical results from silicophosphate and from Bessemer basic slag.

Silicophosphate can be regarded as having much the same value as a very high-grade high-soluble basic slag. It may replace superphosphate for many purposes where soils are very acid, but on less acid and neutral soils it is inferior to superphosphate. There is no agricultural justification for producing silicophosphate, unless it can be sold more cheaply than superphosphate per unit of P_2O_5.

Basic Superphosphate Mixtures and Dicalcium Phosphate

In the 1941-46 experiments attempts were made to improve the efficiency of phosphate fertilizers. Water-soluble phosphate reacts with soil very rapidly; less-soluble forms, such as dicalcium phosphate, may react more slowly. Mineral phosphate cannot be converted to dicalcium phosphate merely by using less sulphuric acid than is

needed for superphosphate. Instead, monocalcium phosphate must first be prepared and then converted to dicalcium phosphate by adding a basic material. Products containing dicalcium phosphate were made by mixing slaked lime or serpentine with superphosphate. (It had been claimed in New Zealand [2], that phosphorus in super-serpentine mixture was more effective than phosphorus in superphosphate.) Dicalcium phosphate, made industrially by dissolving phosphate rock in hydrochloric acid and then adding milk of lime to the solution, was tested from 1951 to 1953. Dicalcium phosphate is present in most phosphate fertilizers made by dissolving phosphate rock in nitric acid followed by ammoniation, and it is also formed when superphosphate is treated with ammonia.

BASIC SUPERPHOSPHATES

Mixtures of superphosphate and lime gave practically the same yields of swedes as equivalent superphosphate, but the mixture with serpentine had only three-quarters of the efficiency of superphosphate. For potatoes grown on acid soils, the mixtures with lime and with serpentine behaved similarly and were practically equivalent to superphosphate. On neutral soils superphosphate-lime mixture was only half as efficient as superphosphate but the mixture with serpentine had four-fifths of the efficiency of superphosphate. There was no evidence in any of the experiments on arable crops of increased efficiency which would justify the expense of mixing superphosphate with basic material. In work on the establishment of reseeded grassland on very acid soils, mixtures of superphosphate with serpentine were slightly more efficient than superphosphate.

DICALCIUM PHOSPHATE

Experiments on potatoes were carried out in 1951-53 to test dicalcium phosphate and the results, summarized in Table 2, were used to calculate the percentage superphosphate equivalents set out in Table 6. Dicalcium phosphate was more efficient than superphosphate on very acid soils ; on less acid and neutral soils it was inferior to superphosphate.

Table 6

Percentage Superphosphate Equivalents of Dicalcium Phosphate derived from Experiments on Swedes and Potatoes in 1951-53

Type of Soil	Percentage Superphosphate Equivalents	
	Swedes	Potatoes
Very acid (*below* pH 5.5)	97 (10)	122 (10)
Acid (pH 5.6-6.5)	85 (22)	62 (15)
Neutral (*above* pH 6.5)	95 (3)	88 (9)
All soils	89 (35)	90 (34)

Numbers of experiments are given in brackets.

In the 1951-53 investigation there were 35 experiments on swedes; the yields recorded are summarized in Table 2. Percentage superphosphate equivalents calculated from the detailed results are shown in Table 6. Phosphorus supplied as dicalcium phosphate had approximately 90 per cent of the efficiency of phosphorus in superphosphate on all kinds of soils; there was little tendency for the efficiency to decrease with increasing soil *p*H.

Dicalcium phosphate dihydrate in powder form (the material used in this work) could replace superphosphate for many crops on slightly acid or acid soils. It might not be so satisfactory on calcareous soils or for crops which require a rapid start from phosphate drilled near the seed. For these purposes water-soluble phosphates are likely to be best.

Nitrophosphates

Several methods of treating phosphate rock with nitric acid have been developed in recent years. When sulphuric acid is replaced by nitric acid in the ordinary superphosphate process, the product contains monocalcium phosphate and calcium nitrate and is too hygroscopic for satisfactory storage and use on the farm. Commercial nitric acid processes differ in the way in which the excess of calcium nitrate is dealt with.

When phosphate rock reacts completely with nitric acid, phosphoric acid and calcium nitrate are formed. After treating this reaction mixture with ammonia, the product contains dicalcium phosphate, ammonium nitrate, and calcium nitrate. Nitrophosphates made by three important processes described below, which use different methods of dealing with surplus calcium nitrate, were tested in experiments carried out in 1952-53.

1. *Addition of soluble sulphate*, such as ammonium sulphate, prevents calcium nitrate occurring in the final product since calcium sulphate is precipitated.

2. *Mixtures of sulphuric and nitric acids* give reaction slurries containing calcium sulphate, calcium nitrate and monocalcium phosphate. After ammoniation, the resulting fertilizer contains calcium sulphate, ammonium nitrate and dicalcium phosphate.

3. *Removal of calcium nitrate*. Solutions of rock phosphate in nitric acid are cooled, half of the calcium nitrate is precipitated, removed, and sold as a straight fertilizer. By neutralizing the remaining solution with ammonia, a nitrophosphate is produced which consists of ammonium nitrate and dicalcium phosphate.

The average yields obtained in all experiments on nitrophosphates are stated in Table 7. The centres were divided into two groups,

experiments on acid soils (pH 6.5 and below) and on neutral soils (pH 6.6 and above) being averaged separately. Percentage superphosphate equivalents of the nitrophosphates, derived from average yields in the potato and swede experiments, are given in Table 8.

Table 7

Yields of Potatoes, Swedes and Grass in Experiments comparing Nitrophosphates with Superphosphate

Phosphate Tested	P_2O_5 applied	Potatoes (18 *experiments*)	Swedes (12 *experiments*)	Grass (20 *experiments*)
	cwt. per acre	*tons of tubers per acre*	*tons of roots per acre*	*cwt. of dry hay per acre*
No phosphate ...	—	10.1	12.7	46.6
Superphosphate	0.30	10.9	17.2	50.2
	0.60	11.8	19.9	50.4
Nitrophosphates made by:				
Adding $(NH_4)_2SO_4$	0.45	11.1	18.8	49.9
Mixed $HNO_3+H_2SO_4$	0.45	10.9	18.5	49.4
Removing $Ca(NO_3)_2$ ...	0.45	10.5	18.5	49.1

Table 8

Percentage Superphosphate Equivalents of Three Types of Nitrophosphates in Experiments on Potatoes and Swedes

Type of Soil	Number of Experiments	Nitrophosphates made by:		
		Adding Ammonium Sulphate	Mixed Nitric and Sulphuric Acids	Removing Calcium Nitrate
POTATO EXPERIMENTS				
Acid (*below* pH 6.5) ...	11	88	66	34
Neutral (*above* pH 6.6)	7	51	52	20
All soils	18	78	62	33
SWEDE EXPERIMENTS				
Acid (*below* pH 6.5) ...	11	104	90	94
Neutral *(*above* pH 6.6)	1	—	—	—
All soils	12	103	96	97

*Superphosphate equivalents have not been calculated for the single experiment on neutral soil.

Potatoes

All three nitrophosphates were inferior to superphosphate for potatoes, and they were more effective on acid soils (*p*H below 6.6) than on neutral soils. In each group of soils, the product made by removing calcium nitrate was inferior to the other nitrophosphates. On the average of all experiments on acid and neutral soils, nitrophosphate made by adding ammonium sulphate gave yields similar to those given by three-quarters as much phosphorus applied as superphosphate; the product made with a mixture of nitric and sulphuric acids was about two-thirds as effective as superphosphate, and the product made by removing calcium nitrate was only one-third as effective.

Grass

In the group of experiments on acid soils and also on the average of all the grassland experiments, superphosphate supplying 0.3 cwt. P_2O_5 per acre was sufficient for maximum yields of hay. Since the superphosphate response curves obtained in these grass experiments are quite flat, superphosphate equivalents for the nitrophosphates tested may be misleading and have not been calculated. Both on acid and on neutral soils nitrophosphate made by removing ammonium sulphate was slightly superior to the other nitrophosphates. All three kinds of nitrophosphate gave lower average yields of grass than superphosphate supplying two-thirds as much phosphorus.

Swedes

Phosphorus in nitrophosphates was practically equivalent to phosphorus in superphosphate for swedes and the three nitrophosphates behaved similarly.

In the different years of these experiments the same kinds of nitrophosphates have given variable results. It seems that the manufacturing processes need further investigation so that stabilized products with consistent performances can be marketed. It is not certain that differences between the agricultural values of different kinds of nitrophosphates depend essentially on the processes which were used to make them. Phosphate in nitrophosphate behaves in much the same way as that in high-soluble basic slag. A tentative conclusion from these experiments is that a fair price for phosphorus in fertilizers of this kind is three-quarters of the price of water-soluble phosphates. Although products containing dicalcium phosphate may give good results on very acid soils, such soils should be limed in the interests of full production. It is not in the interests of farmers, nor is it practicable, to suggest that soils should be under-limed merely to allow the crops to use certain kinds of phosphate fertilizer.

Valuation of Phosphate Fertilizers by Laboratory Tests

The experiments summarized here have confirmed the usefulness of the citric acid test for valuing powdered fertilizers like basic slag, silicophosphate and dicalcium phosphate. For ground rock phosphates no chemical test affords a satisfactory valuation and it is more important to have a description of each product and to know the district from which it is mined.

Although conventional solubility tests may be suitable for valuing powdered phosphate fertilizers, further work in field and laboratory is needed before the newer kinds of granular fertilizers containing dicalcium phosphate may be valued by laboratory tests. It may be misleading to rely solely on the citric acid or citrate tests in pilot plant development. Of the nitrophosphates tested, only that made by adding ammonium sulphate contained an appreciable amount of water-soluble phosphorus (28 per cent of the total phosphorus present). The products made by using mixed nitric and sulphuric acids and by removing surplus calcium nitrate had high solubilities in 2 per cent citric acid (100 per cent and 96 per cent respectively). The material made by adding ammonium sulphate was less soluble (89 per cent) in citric acid; its superior performance may be due, in part, to the relatively high proportion of water-soluble phosphorus which it contained. At present the development of new granulated phosphates which contain little or no water-soluble phosphate can only be guided by agricultural tests in glasshouses and in fields.

These experiments have emphasized the merits of water-soluble phosphate on most, if not all, classes of land. Although other tests are needed for special types of phosphate fertilizer, formal simplicity should not be secured at the cost of sacrificing the water-solubility test for superphosphate, ammonium phosphate and mixtures based on them. Newer methods of manufacturing are likely to be introduced in the United Kingdom to cheapen costs of production, and to obtain high-analysis fertilizers with suitable ratios of plant nutrients. Anhydrous ammonia is both concentrated and cheap, and it may become convenient to ammoniate superphosphate or to make nitrophosphates here. The valuation of granular fertilizers containing dicalcium phosphate may become an increasingly urgent problem as fertilizer consumption increases.

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RAINFALL AS A FACTOR INFLUENCING THE YIELDS OF POTATO CROPS

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The possibility of obtaining increased yields of certain crops by means of irrigation in Britain is widely appreciated. There is, however, a distinct lack of valid information concerning the optimum water requirements of the majority of our crop plants. Such knowledge must be the fundamental factor governing the economic application of water to a growing crop, and in view of this lack of information and the increasing interest in irrigation on the part of many advisers and farmers, the following data, which have accumulated over the years with potato crops at Sutton Bonington, should be of interest.

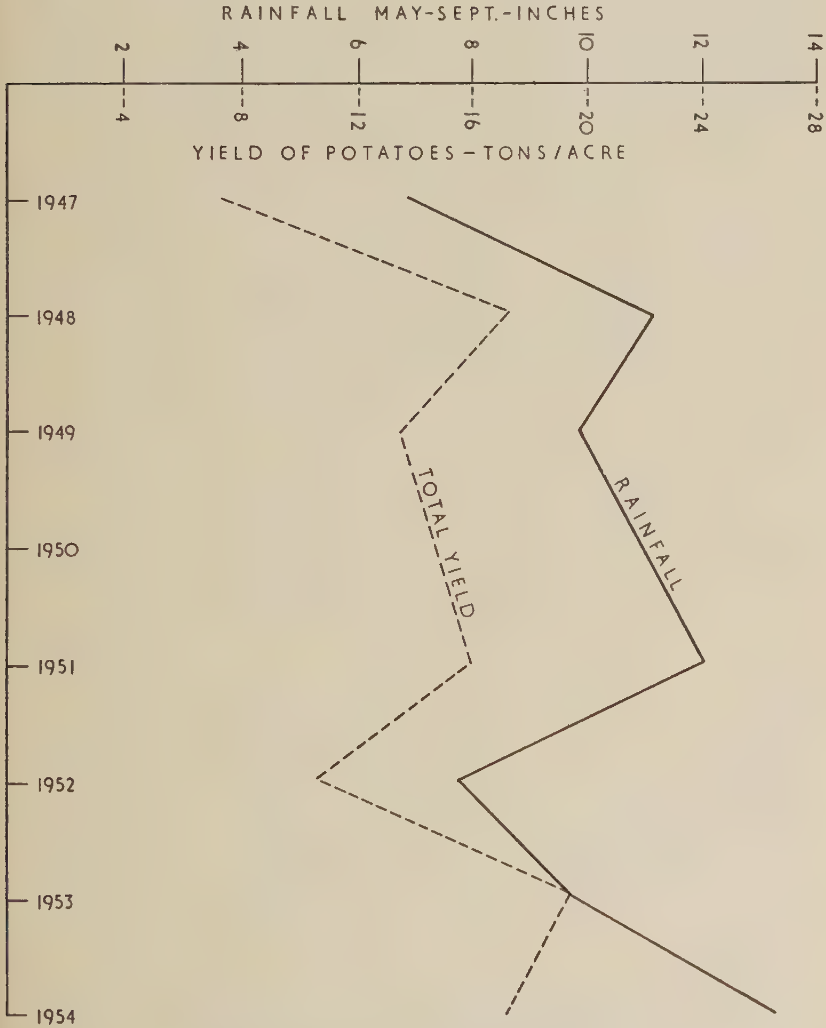
The trials from which these results have been gathered were replicated trials, but they were not expressly designed for the study of water relationships. The figures are presented here as an attempt to explain wide seasonal differences in yield of potatoes and they may be used, with appropriate caution, as an indication of possible increases which might be anticipated from efficient irrigation.

The yields are those of healthy stocks of Majestic, and in each season cultural practices have been very similar, apart from 1947 when planting was later than normal owing to bad weather. Seed was chitted and the rotational aspects, manuring and general crop management did not vary. In addition, although on different fields over the years, the soil type and fertility levels were not considered to be materially different. The major variation over the years has been rainfall, and the relationship between yields and rainfall during the months of May to September inclusive, is shown in the following table :

Year	Rainfall May-Sept.	Yield of Ware	Total Yield of Crop
	inches	*tons per acre*	*tons per acre*
1947	6.87	6.0	7.3
1948	11.12	14.1	17.1
1949	9.82	12.7	13.5
1950	10.82	11.8	14.6
1951	11.92	10.8	15.8
1952	7.71	6.0	10.5
1953	9.66	17.2	19.2
1954	13.16	12.6	17.0

The period May to September inclusive has been selected in the belief that rainfall during the growing period of the crop is of greater importance than the total rainfall over the year, much of which is never available to the crop.

The relationship between rainfall and yield of crop is further demonstrated in the diagram on this page.



The relationship between rainfall and yield

It is claimed that rainfall during the growing period exerts a considerable effect on the yield—a phenomenon which is well known even to those remotely connected with the land but concerning which little quantitative data exist. Obviously other environmental factors come into play, as witnessed by the results in 1954 when water was in super-abundance but when growth was probably limited by abnormally low soil temperatures and lack of sunshine. The important points arising from these data are the magnitude of the range of seasonal variation in yield and the encouragement this gives to the investigation of the practical possibilities of irrigation when, in a warm dry year, other environmental conditions will permit appreciable response on the part of the crop.

CORRECTION

N.A.A.S. Quarterly Review No. 26, page 77, line 6.

Substitute "*J. Dairy Res.*, 1954, **21**, 172."
for "*J. Dairy Sci.*, 1954, **21**, 172."

ABSTRACTS

ANIMAL NUTRITION

The Requirement of the Dairy Cow for Fat

Improvements in the methods of extracting oil from oilseeds have been made in recent years and have resulted in the production of feedingstuffs which contain very little residual oil. Many of the entries for oilcakes and meals which appear in old tables of feedingstuffs are now incorrect because they indicate considerable percentages of fat. These figures are true only for obsolete pressure processes, because modern solvent-extraction methods are such as to leave almost negligible amounts of oil in the feedingstuffs. The nutritional value of the modern oilcake meal is different from the earlier varieties in several ways. For instance, its energy content is less than it used to be because the loss of the highly calorific fat is not compensated by the concomitant slight increase in the much less calorific proteins and carbohydrates. Again, if the oil is normally a source of fat-soluble vitamins, the feedingstuff will carry less of these. Finally, there is evidence that some of the more unsaturated fatty acids are important to health and probably cannot be manufactured by rumen bacteria [1].

Since a cow giving 4 gallons of milk of average fat content produces over 1½ lb. of fat, it is not surprising that a great deal of work has been done to ascertain what effect the fat in the cow's ration has upon the quantity and quality of the milk produced. In the following paragraphs only a few recent papers will be mentioned, but a very useful list of thirty-six publications is to be found at the end of the paper herein referred to as [6].

Russia

Russian workers [2] studied the effect of linseed cake given at two substantial levels, viz., approximately 1½ lb. and 2½ lb. per gall. of milk produced. Taking the levels of milk yield and fat percentage in a control group as 100, the respective figures for the lower linseed cake level were 106 and 107, and for the higher 111 and 112. The butter from the higher group was yellower, softer, and of inferior keeping quality; the lower level of linseed cake feeding was accordingly suggested as the maximum to be used. (Since this paper was seen only in abstract form it is not possible to supply details of the fat intake, etc.)

America

American work [3] on linseed cake meal was carried out over 100 days on two groups of 13 cows each, using expeller meal with 4.43 per cent oil and solvent-extracted meal with 1.34 per cent. A further trial compared the expeller meal with extracted meal which contained only 0.84 per cent

oil. In both trials, the linseed cake meals accounted for one quarter of the concentrates fed, the remainder of the concentrates being maize meal ($\frac{2}{5}$), oat meal ($\frac{1}{4}$), and bran ($\frac{1}{10}$). The mixture was fed at the rate of 1 lb. for every 3 lb. of milk produced which corresponds to 0.86 lb. of linseed cake meal per imperial gallon. The fat contents of the " expeller-meal " concentrate mixture and of the " extracted-meal " concentrate mixture in the first trial were 3.33 and 2.54 per cent respectively, and in the second trial 4.35 and 3.42 per cent. The remainder of the ration consisted of equal amounts of silage for the different groups, and alfalfa hay *ad lib*. (No record of the hay was kept, but the authors hoped that the extra energy of the higher oil ration would be compensated by an increased consumption of hay by the animals on the lower oil diet. It is true that this assumption need not be correct, but gains in body weight for the two groups were almost the same, and the diets were obviously both more than adequate.) There was no significant difference at the 1 per cent level between the groups in the fat percentage of the milk, in the amount of fat-corrected milk* produced, or in the weight of concentrates consumed per lb. of fat-corrected milk.

All the animals gained weight during the trials and the great diminution of fat due to the solvent-extraction process did not cause a reduction in the " bloom " effect for which linseed is noted.

Germany

In a third experiment, this time in Germany, a switch-over technique was employed with 74 cows, each giving about 4 gallons daily, whereby the groups were all given in turn palm kernel cake or meal (or coconut cake or meal) containing 1, 2.5 or 5 per cent of fat [4]. The cake accounted for 60 per cent of the production ration which was kept constant in all other respects ; the maintenance ration was also the same in all cases. No difference in effect was produced by changing from the cake with 1 per cent fat to the cake with 5 per cent fat in respect of milk yield or body weight, but the 5 per cent cake increased the fat percentage of the milk by 0.15 which, although a slight change, was significant.

Denmark

The matter has also been investigated in Denmark [5] in a series of experiments which showed that a definite advantage was to be obtained from high-fat rations. In the first of the series, pressed linseed cake, extracted linseed meal and linseed itself were fed along with roughage to three groups of cows, the digestible fat of the rations being 229, 112 and 580 g. respectively (453.6 g. = 1 lb.). The respective yields of

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*This represents an attempt to bring milk yields to a common basis so that fair comparisons may be made. This basis is reached by calculating how much standard milk, with 4 per cent fat and of constant energy value per unit of weight, is equivalent to the milk obtained in the experiment.

The formula is :

lb. of 4 per cent fat-corrected milk $=(0.4 \times$ lb. of milk obtained$)+(15 \times$ lb. of fat obtained).

THE 1953 SEA FLOOD DISASTER IN LINDSEY, LINCOLNSHIRE (See pp. 125-34)

Toxic effect of sea water on vegetation—the lighter areas were flooded

Tolerance of plant species areas where wheat has been killed and patched with ryegrass

PLATE I

Mosaic pattern on dried-out flooded land

Close-up of crop on dried-out flooded land

PLATE II

 (See pp. 125-34)

Ponding on land not treated with gypsum

Effect of gypsum on soil structure only the darker coloured soil on right has been treated. Note the improved soil structure and better plant emergence

PLATE III

THE 1953 SEA FLOOD DISASTER IN LINDSEY, LINCOLNSHIRE (See pp. 125-34)

Effect of cultivations on subsequent cropping. Much better cereal stand on area to right receiving rotary cultivation.

fat-corrected milk were 15.99, 14.60 and 16.97 kg. (1 kg. milk has a volume of 0.214 gall., and 1 gall. weighs 4.67 kg.). The second trial also had three groups : a control, an addition of 117 g. rape oil, and one of 91 g. soya bean oil. The fat intakes were 194, 321 and 294 g. and the milk yields 13.91, 15.28 and 16.00 kg. The third trial of the series compared a basal ration containing 100 g. fat with one to which lard had been added to bring the fat content up to 292 g. On this occasion the milk yields were 15.33 and 17.15 kg. respectively. Lastly, three groups of cows were given the same amounts of roughage but different concentrate mixtures, so that the fat intakes were 192, 254 and 252 g. digestible crude fat. The yields were 13.96, 14.41 and 14.48 kg. respectively.

The results of these Danish experiments indicate a correlation between milk yield and the fat content of the diet, and the butterfat produced on the high-fat rations was of a desirable softer character. It may be that the discrepancy between the American and Danish findings on the effect of linseed cake can be partly explained by the fact that there were much greater differences in *total* fat in the Danish experiments than in the American. The fat contents of the American concentrates were 151 and 115 g. per 10 lb. of " expeller " mixture and " extracted " mixture respectively in the first trial, and 197 and 155 g. in the second. The differences, 36 and 42 g., are smaller than those in the Danish experiments, and if the fat contributed by the silage and alfalfa hay had also been taken into account, the *total* fats would probably show only a small *relative* difference between the groups. The effect of an extra 40 g. of fat on a ration already adequate in fat might not be significant. (*N.B.*—The 10 lb. postulated in this calculation was chosen merely as a convenient figure. It represents, of course, the concentrate allowance for 3 gallons of milk.)

Holland

The last work to be considered is a series of experiments carried out in Holland [6]. In this series the cows were conditioned to low-fat diets for a long time beforehand. The mixture consisted of extracted linseed meal, extracted ground-nut meal, and extracted coconut meal, with feeding-stuffs naturally poor in fat, such as barley meal, beet pulp, dried potatoes, tapioca and molasses. This mixture was continued as the concentrate ration for the low-fat group of cows in the experiments proper, and the high-fat ration differed merely in that the corresponding pressed meals were substituted for the three extracted oilseed meals. The energy contents of the two rations were equalized by leaving out some starch from the high-fat one. The fat percentage of the low-fat mixture was 1.25 per cent and of the high-fat 3.34 per cent, and approximately 11 lb. of the mixtures were fed per head daily to the appropriate groups. Roughage was the same for both groups of animals and was provided by silage and hay which had 6.14 and 2.15 per cent of oil respectively in the dry matter ; 42 lb. of silage and 14½ lb. of hay being given to each cow. In the total rations, the fat intakes were 420 g. for the low-fat and 523 g. for the high. The result of this trial was that no significant differences were found for live weight,

body condition or standard milk (corrected to 3.33 per cent fat); the only significant difference was that the high-fat ration gave an increase in milk-fat percentage of about 0.12.

Second Trial

In the second type of trial in this series, between 7 and 8 lb. of concentrates were fed, the fat contents of the " extracted " and the " pressed " being 0.62 and 4.8 per cent respectively. Again, both groups received the same quantities of roughage, but this time silage was omitted and 66 lb. fodder-beet plus 4½ lb. rye straw were given with 13 lb. hay. The dry matter of the hay and beet had 2.15 and 0.24 per cent fat respectively. The total daily fat in the low ration was 144 g. and in the high 288 g. This time there was a marked difference in milk yield (1.65 kg.) and in fat (63.6 g.) in favour of the high-fat group. A repeat experiment at another centre, where the hay contained 2.65 per cent fat and the total rations 172 g. and 306 g. respectively, gave similar but slightly less marked increases of 1.00 kg. in yield and 32.8 g. in fat. The fat percentage in the milk was unaltered.

Third Trial

A third trial repeated the second, except that the extracted mixture was not quite so poor in fat, having 1.52 per cent, but in this instance the pressed mixture was also higher with 5.79 per cent. This trial was conducted in two parts: in the first, 15½ lb. of clover hay and 66 lb. of fodder-beet with some straw was fed; in the second, grass hay replaced the clover. The beet contained 0.38 per cent fat, the clover hay 1.94 per cent, and the grass hay 3.05 per cent, all on the dry matter basis. The low and high-fat rations in the first part contained 188 g. and 339 g. fat, and in the second part 249 and 373 g. The milk was increased in the first part by 1.19 kg. and in the second by 0.92 kg. when the high-fat ration was given; the increases in milk fat were 46.8 and 27.0 g. Again, the fat percentage was the same in the milks of both groups.

Conclusions on Dutch Experiments

These experiments are valuable in that they have brought out the following points:

(*a*) that the nature of the roughage has a marked effect;

(*b*) that if silage and hay are fed the concentrates can contain less fat (in these experiments a content of 1.5 per cent would probably have sufficed) for optimum production than if roots and hay are given (in which case the concentrates might require at least 4 per cent of fat);

(*c*) a daily amount of between 300 and 400 g. crude fat from roughage and concentrates together would probably give adequate milk production.

The possibility was not overlooked that the effect of the roughage may depend more on other properties than on its fat content—that is to

say, properties influencing the production from fibre, during ruminal fermentation, of fatty acids which would be used after absorption for fat synthesis in the mammary gland. The final conclusion reached was that it would be wise to safeguard optimal milk production against any unpredictable irregularities of ruminal function by giving sufficient preformed crude fat in the total feed.

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S.M.B.

MACHINERY

N.I.A.E. Tractor Test Reports Nos. 88, 96 and BS/N.I.A.E./54/11

Report No. BS/N.I.A.E./54/11 describes a British Standards Test of the County Four-Wheel Drive tractor carried out in September 1954. This machine has a Fordson Diesel engine unit, is fitted with 13-24 pneumatic tyres on its front wheels as well as at the rear, and is steered by clutch and brake instead of by front axle.

In the drawbar tests, a maximum operating horsepower of 34.3 was attained at 4.29 m.p.h. with a pull of 3,000 pounds, and 30.6 at 1.63 m.p.h. with a pull of 7,050 pounds. The best fuel consumption was 16.4 drawbar horsepower hours for a gallon of fuel.

This is the first test of its kind made in Britain of a four-wheel drive tractor, and this tractor happens to have the same size and kind of engine as that fitted in a two-wheel drive tractor and a crawler tractor for which nearly similar tests were made in 1953. Figures are therefore provided which help in an assessment of the usefulness of four-wheel drive mechanisms in tractors, though since the British Standards drawbar

test of pneumatic tyred tractors is carried out only on a tarmacadam surface, *the figures give no certain guide to the performance to be expected from the four-wheel drive tractor when it is working in adverse agricultural conditions.*

A Fordson Diesel two-wheel drive tractor with 14-30 rear tyres was the subject of an N.I.A.E. test in June 1953 which was reported as Test No. 96 ; the County Crawler tractor with Fordson Diesel engine was tested in November 1953, and was reported upon as Test No. 88.

Performance Comparisons

The forward speeds in the various gears at the rated engine speed of 1,600 r.p.m. are a little different in the three tractors, but nevertheless an interesting comparison of power outputs can be made. The operating maximum drawbar horsepower recorded for the two-wheel drive tractor was 31.4, for the crawler tractor it was 33.3, and for the four-wheel drive tractor 34.3. The two-wheel drive tractor on tarmacadam pulled 4,700 pounds at 1.94 m.p.h., the crawler on dry grassland pulled 9,500 pounds at 1.24 m.p.h., and the four-wheel drive tractor pulled 7,050 pounds at 1.63 m.p.h. in the B.S.I. test.

The maximum sustained pull recorded for the two-wheel drive tractor was 5,350 pounds, for the crawler tractor it was 10,500 pounds, and for the four-wheel drive tractor it was 7,750 pounds.

The best fuel consumption recorded for the two-wheel drive tractor was 14.8 drawbar horsepower hours per gall. at a pull of 3,600 pounds, and this was equalled by the crawler tractor although at a 6,700 pounds pull. The four-wheel drive tractor gave 16.4 drawbar horsepower hours per gallon ; the range of pulls over which the consumption was within 10 per cent of this figure being 2,850-6,100 pounds.

In the four-wheel drive tractor the tyres were 75 per cent water-ballasted. The weight of the tractor and operator was 9,240 lb., and the weight on the rear wheels was 4,510 pounds. The two-wheel drive tractor had its rear tyres 95 per cent water-ballasted and it was also fitted with wheel weights. The total weight of the tractor and operator was 7,420 pounds and the weight on the rear wheels was 5,320 pounds. The weight of the crawler tractor with operator was 8,395 pounds.

Experience will show how the maintenance costs (including tyre replacements) of the four-wheel drive tractor will compare with those of the two-wheel drive tractor and the crawler, and also how the four-wheel drive machine fares under difficult conditions. In the conditions of the tests described in these three reports, four-wheel drive seemed to give a better performance than two-wheel drive, though the high pull of 10,500 pounds recorded for the crawler on dry grassland was not approached by the four-wheel drive on the B.S.I. test surface, in spite of the heavier weight of the four-wheel drive tractor.

H.J.H.
C.C.

Economics of Spraying with Various Types of Machine.

The Economics of Crop Spraying. *Farmers' Bulletin No.* 16, Cambridge University Farm Economics Branch, 1954.

With almost 20,000 field crop sprayers now being used on British farms it is not surprising that farm economists have been examining the various economic aspects involved. Many farmers today have difficulty in deciding whether to own and operate their sprayers, and which of the many types of machine available would be best for their needs. A study made by the Cambridge University Farm Economics Branch gives some guidance on such problems. This report covered 40 low-volume and 24 high-/low-volume sprayers situated in three distinct farming areas in the eastern counties. The low-volume sprayers dealt with an average of 160 acres annually, while the high-/low-volume machines averaged 361 acres.

Average costs per acre to operate these machines, *excluding materials*, were estimated on 1954 prices to be as follows :

Item	Low-Volume	High-/Low-Volume
	s. d.	*s. d.*
Depreciation	2 11	4 8
Interest on Capital	6	10
Repairs	1	4
Maintenance	2	1
Fuel (*excluding tractors*) ...	—	3
Labour (@2*s.* 10*d. per hr.*) ...	1 2	1 6
Tractor (@4*s.*-4*s.* 8*d. per hr.*)	1 7	1 10
TOTAL ...	6*s.* 5*d.*	9*s.* 6*d.*

Labour and tractor costs accounted for 43 per cent of the total in the case of low-volume sprayers and 35 per cent with the high-/low-volume machines. The capital cost of the low-volume machines was put at £80 and that of the high-/low-volume machines at £380, although it was noted that a new type of 100-gall. high-/low-volume mounted machine could be bought for £250. Depreciation charges, based on the higher capital cost figure for the high-/low-volume machine, averaged 53 per cent for the low-volume and 58 per cent for the high-/low-volume machines.

Whenever an attempt is made to assess the cost of using various types of farm machines, the answer obtained may be misleading unless it is qualified in detail as to the conditions. This applies to comparisons between the cost of using a cheap low-volume sprayer and a much more expensive high-/low-volume machine to do a similar job. It is difficult to assess the actual performance of the machine, or the advantage of being able to perform the task really effectively. " Timeliness " is a factor that is almost impossible to assess accurately, but it is certainly of such importance as to outweigh small differences in the cost of getting the work done, and the higher cost of a high-/low-volume machine on low-volume work might be justified if its use resulted in more timely

work. Similarly, any comparison between getting the work done by contract and doing it with one's own machine must turn largely on the factors of timeliness and effectiveness of the operation.

In the case of the Cambridge Report, depreciation charges were based on the assumption that no machine, however little it is used and however well looked after, will be worth anything after eight years; while a machine that does 200 acres or more annually will be completely worthless in six years. One of the reasons given for this rather short life is the fact that the machine may become obsolete in a short period. Method and quality of construction is not taken into account so far as depreciation is concerned, though it could well be argued that the high-/low-volume machines, if properly cared for, could have a longer life than typical low-volume types. The conclusion was reached that even though a high-/low-volume machine is used to spray a very much bigger acreage than a low-volume machine, and although the former was found to cover 45 acres a day compared with 30 acres a day by the latter, the high-/low-volume machine always costs more to operate on low-volume work. It was only when depreciation and interest charges were ignored altogether that the high-/low-volume machine was found to be as cheap to operate on low-volume work.

Other interesting conclusions were that 30 acres of low-volume spraying work would justify the purchase of a low-volume sprayer ; that purchase of a £250 high-/low-volume sprayer could be justified if required for not less than 48 acres of spraying of suspensions that need to be applied at high volume, and that expenditure of £380 on a sprayer would be as economical as hiring a contractor to do the job if 66 acres of difficult high-volume work needed to be tackled annually.

It might be more satisfactory, in attempting to compare multi-purpose sprayers with the simpler types, to split the capital cost of the multi-purpose machine into two parts. Thus, if the more complete sprayer costs £250 and the low-volume machine costs £80, one could argue that £80 out of the £250 is chargeable to the low-volume work, leaving a balance of £170 to set against the jobs that need the more expensive form of construction. On this basis, a very moderate acreage of high-volume work anually would justify the extra expenditure.

C.C.

FRUIT

The Cost of Growing Apples 1948-51. R. R. W. FOLLEY, Wye College. Economics of Fruit Farming Report No. 2, 1954.

The economics of fruit growing are of vital interest to growers and advisers alike, especially at the present time when the costs of materials and labour are rising steadily without comparable increases in the market returns for horticultural produce. The Economics Department of Wye College is attempting to cover this wide field and the recent report is full of valuable information.

Cost accounting was carried out from 1948-51 on 311 acres of bearing apple trees on six farms in Kent and Sussex. Only one of these farms was exclusively devoted to apples, the others included some of the following : market garden and farm crops, dairy farming, soft fruit, hops and pasture. On all farms the apples, both culinary and dessert, formed the most important sources of income. The figures, therefore, serve as a guide to the costs of apple growing on mixed farms.

The costs are based on the average of several different plantations on each farm. In some cases figures for dessert apples may include those for a few culinary apples and vice versa. Standard trees of culinary varieties in grass were only lightly represented in the survey and none of the orchards was grazed. Between 1949 and 1952 costs rose about 7 per cent per year, but all the comparisons between farms were adjusted to 1951 prices. No late spring frosts occurred during the years concerned.

No income or profit figures are given, but the income of these farms exceeded expenditure in 15 out of the 16 crop-years. The costs are all moderately high for the type of production, which means that the growers were all farming fairly intensively. At present it seems profitable to spend rather heavily to get high quality fruit that will command the best price, but if the price for high quality fruit drops, production cost will become a more important factor.

Folley emphasizes that no attempt should be made to use the figures presented as a guide to the economic cost for any operation, nor as a measure of the efficiency of management. Their chief value lies in showing approximately how much the cost of a bushel goes up as yield per acre goes down and to emphasize the importance of studying methods of raising yield per acre.

Discrepancy between "Cost" Figures and Grower's Expenditure

It is sometimes hard to understand why " cost " figures are as a rule lower than the actual amount spent by the grower. The main reason is that these figures relate to the value used up in the process of producing the apple crop and they do not take into account the improvements in the farm that most growers are constantly making. Furthermore, the payment of regular labour all the year round is ignored, and labour is charged for only as it is used for specific work in the orchards ; fertilizers are usually bought in quantity but only the part used is charged to " costs " ; and in services, such as tractors and other machinery, depreciation is charged on the actual hours of use, instead of according to a scale of allowances, as would be done by an accountant. Interest on capital is also included.

The total cost may include a proportion of some non-recurring charges, even though the grower makes no payment on the item during the year, e.g. tree grubbing and grassing down. The yearly cost is like a reserve being built up to pay the charge when it becomes due. As complete information was lacking, the initial marketing costs are omitted, though it is suggested that grading, transport to market, market charges

and salesman's charges may account for as much again as the whole growing process.

The effective cost per bushel is calculated by dividing the total cost by the number of bushels *marketed* to advantage. The average cost per bushel marketed will rise as the proportion of cull fruits rises, but in this paper the cost per bushel refers only to the total cost divided by the number of bushels *picked*.

Expenditure per acre relates to the expenditure on the operation divided by the whole costed acreage, not just by the acreage so treated. Thus the calculated figure shows the size of the burden that the operation throws on orchard costs as a whole.

An interesting part of total costs is the "proprietor's sacrifice". An estimate is made of the probable initial investment in the fruit farm, excluding provision for packing and storage. The yearly charge necessary to provide its repayment fifty years later is calculated. The first part of this charge is interest at 3½ per cent on the value of the farm and buildings and the second is the amount of money to be put away each year for the forty-two years of bearing life (while trees are between nine and fifty years old). This is allowed to accumulate at 3½ per cent to recreate the money value of the tree-capital, and the cost of eventually grubbing the trees.

Details of Annual Outlay

Cost figures for each of the six farms are presented in detail in three tables showing current outlays over two years, and operational and factor costs in the same years, with the equivalent 1951 price. Particulars are given of the nature of each holding and valuable comments are made on the data.

Taking the farms together it seems that an annual outlay of £100 an acre is necessary, giving a cost per bushel picked of about 6s. 7d. and an expenditure of manual labour of some 320 hours per acre.

Tendencies towards constant quantities between the farms were shown by cultural costs, which amount to about 60 per cent of the total costs, and if picking is included, to almost 77 per cent, and labour costs, which amount to 45 per cent of the total cost. If labour and services are considered together, an even more constant figure around 60 per cent of the total cost is reached, which emphasizes the complementary nature of labour and machinery costs.

The costs per acre of services did not diminish as the area of the orchards increased, and it seems that 25 acres can be mechanized as economically as 100 acres ; possibly the really efficient mechanization of the large farm has yet to come. The larger farm does, however, show an advantage in the number of bushels produced per £1 spent on services and this must be due to higher yields per acre.

The relative constancy of these aggregate quantities suggests a uniformity of methods of apple growing, that is probably the result of the widespread adoption of the findings of research and experience. With so much of the expenditure arising from items that the grower apparently cannot modify appreciably, he must obviously ensure that the operations concerned are efficiently performed and that amongst the costs that are variable, money is spent wherever it is likely to result in an increase in the quantity and quality of the crop. The cost per bushel is chiefly influenced by the number of bushels produced.

Taking the sixteen crop-years as a whole, 4,922 man-hours produced 4,806 picked bushels of apples ; this works out at about one man-hour per bushel (40 lb.). This figure is correct for culinary apples, but for dessert apples one man-hour produces only 34 lb. If allowance is made for cull fruit and the cost of a possible crop failure, the average cost of growing a saleable bushel of Bramley's Seedling is between 6s. 1½d. and 7s. and for Cox's Orange Pippin between 8s. and 9s. 1½d. The extra cost in the production of Cox's Orange Pippin is chiefly due to the lower yield per acre.

Labour Requirements

The regular labour requirement works out on average as 218 hours per acre, and allowing one man 2,220 productive man-hours and 70 hours overtime during the year, one man is required for 10.5 acres of trees, apart from special operations, e.g., thinning out, grubbing and grassing down.

The figures show that grassed orchards are often no more costly to manage than cultivated orchards ; in fact grassed ones are less costly at low standards of husbandry, but trimming up may increase the total cost of managing grass.

No summary can do justice to the wealth of information in this paper ; it is essential that the original should be carefully studied.

H.B.S.M.

DAIRY BACTERIOLOGY

The Growth of Micro-organisms in Phosphate Buffer without and with added Nutrients. ELLEN I. GARVIE. *J. appl. Bact.*, 1954, **17**, 2, *xxi*.

It has been reported from America that after treatment with a disinfectant, bacterial cells can be reactivated by incubation in a solution of a metabolite in phosphate buffer. If this were indeed the case, it would be of great importance to disinfection studies. Garvie found that *Pseudomonas fluorescens* and *Bact. coli* grew in buffer substrates (Na_2HPO_4 and KH_2PO_4) and that growth proceeded after re-inoculations over many generations.

Growth was not supported by dead cells, nor by nutrients carried over from the original suspension. It was found that in solutions of buffer ingredients of purity greater than that normally used in the

laboratory, there were sufficient available impurities to support growth. It would therefore appear that the American claims should be accepted only with the greatest reserve.

The Growth of Lactic Streptococci in Mixed Starter Cultures. LORNA G. LIGHTBODY and L. J. MEANWELL. *J. appl. Bact.*, 1954, **17,** 2, *xxiii.*

Using ten unrelated strains of lactic streptococci, the authors combined mixtures of three components each and sub-cultured daily at 22° C.

The activity and stability were determined frequently. The activity was well maintained, but in ten out of eighteen cases it was found that one strain had become dominant after a very few transfers.

If a heavy infection of a bacteriophage, active against a dominant strain, was added to a mixture when sub-cultured, incubation for 24 hours at 22°C. resulted in the growth of a subsidiary resistant strain and activity was normal. If a light infection of bacteriophage was similarly added, so that early growth and later lysis of the dominant strain was permitted, the activity was poor.

In many, but not all, cases a strain became dominant because of the production of substances inhibitory to the other components of the mixture. In the absence of such strains, mixtures remained " mixed " for many sub-cultures, but even then one strain was found to be dominant after some ten transfers. In fact, most mixtures became single strain starters after a few transfers. There is nevertheless some virtue in mixed strain starters, because as the dominant strain fails, the subsidiary strains may develop and provide an active starter.

Aroma-producing Group " N " Streptococci isolated from Cheddar Cheese Curd. M. ZIELINSKA and E. R. HISCOX. *J. Dairy Res.*, 1954, **21,** 2, 238.

Acetic acid, CO_2 and acetoin are well-known products of the fermentation in milk produced by *Leuconostoc* and streptococci of the *Str. diacetilactis* group. The authors describe other Group " N " streptococci which are also capable of forming the same compounds in milk. They differ from *Str. diacetilactis* in producing acetoin from the lactose in lactose broth.

The Incidence of Penicillin in Milk Supplies. F. C. STORRS and WINIFRED HIETT-BROWN. *J. Dairy Res.*, 1954, **21,** 3, 337.

The authors carried out two surveys of the incidence of penicillin in milk, following treatment of the cows for mastitis, because penicillin may affect the cheese-making process. Hundreds of samples from the churn and from bulk milk were examined. It was found that bulk milk was in general free from significant concentrations of penicillin, but that some 3 per cent of churn milks contained appreciable quantities.

It was also found that sufficient penicillin to prevent starter growth was present in the mixed milk of a herd of 37 cows up to the fifth milking after treatment.

Enzymes Concerned with Gas Formation by some Coliform Organisms. J. WOLF, L. H. STICKLAND and J. GORDON. *J. gen. Microbiol.*, 1954, **11,** 1, 17.

Some coliform organisms from soil produced acid and gas at 30°C., but only acid with no gas at 37°C. One of the strains also produced no gas at 44°, and also failed to use citrate as a sole carbon source. This is another example of the anomalies, which may be of importance in water analysis, encountered amongst the coliform organisms.

A.T.R.M.

POULTRY HUSBANDRY

Egg Quality

Variations in the quality of newly laid and stored eggs have recently attracted considerable interest. Since the mechanics of storage methods have so vastly improved over the last decade, high grade quality when the egg is laid and a very slow natural rate of deterioration, have become matters of some importance to both the distributors of fresh and stored eggs. "A Survey of Egg Quality at Two Egg-Laying Tests" by A. W. BRANT, A. W. OTTE and G. CHIN (U.S.D.A. *Tech. Bull.*, April 1953, No. 1066) gives an account of some interesting points noted with eggs from two laying trials. The eggs were collected, held at 55°F. for three days to simulate commercial conditions, and then opened and examined. It was found that the albumen quality of the eggs of individual birds was very consistent from day to day, but that there was a remarkably slow decline over the year. Thus, in March, 44 per cent of all eggs were of AA quality (80 or more Haugh units) but only 22 per cent reached this quality grading in August. Marked variations took place within breeds and crossbreeds, but no breed or crossbreed appeared to have any marked advantage or disadvantage. Similar conclusions were reached for shell thickness, i.e. no breed differences were observed, but a general seasonal variation occurred. In August, 41.1 per cent of the eggs were 13/1000ths in. thick or less ; in March only 20.5 per cent were of this quality. (Egg breakage increases rapidly when shell thickness drops below 13/1000ths in.) A finding of particular interest was that there was no significant correlation between rate of production and shell thickness or incidence of blood spots. But there was a highly significant correlation between the March and August observations on the production rate and decline in albumen quality, although high production was not always associated with low albumen quality.

One of the major difficulties of assessing quality in eggs is the absence of any method whereby all those characteristics which are of commercial importance can be included. Various methods are discussed in a paper on "A Comparison of Several Methods for Evaluation of Quality in

Eggs" by V. J. HARNS, E. A. SAUTER, B. A. MCLAREN and W. J. STADELMAN (*Poultry Sci.*, 1954, **33**, 1022-8). In this account, evaluation of physical properties and culinary properties are considered and it is concluded that the albumen index is correlated with other quality measurements except yolk colour.

Incubation

" Studies on Disinfection of Eggs and Incubators " by J. E. LANCASTER, R. F. GORDON and E. G. HARRY (*Brit. Vet. Journ.*, 1954, **110**, 238-46) gives an account of the employment of formaldehyde fumigation at various concentrations. With 3½ oz. formalin per 100 cu. ft. capacity, fumigation over 20 minutes produced a gas concentration (14 mg. per cu. ft.) sufficient to kill *S. pullorum* on the surface of the hen's eggs. To kill the organism after 10 minutes exposure, 5¼ oz. formalin per 100 cu. ft. is required. The hatchability of fertile eggs was not affected when the eggs were fumigated prior to incubation for 60 minutes at a concentration of 22 mg. formaldehyde per cu. ft. at 20 minutes. The practical application of formaldehyde fumigation in the field is discussed, and attention drawn to the leakage and poor distribution of the liberated gas generally observed. It is considered that these are two major factors influencing the efficiency of pre-incubation fumigation under commercial conditions.

Two interesting papers from the Netherlands on the influence on hatching rates of turning eggs have recently appeared. " Incubation Experiments at the State Poultry Institute at Beekbergen " by P. UBBELS (*State Poult. Inst.*, January 1953, No. 50) deals with the hatching rates secured by turning eggs in both large and small incubators over periods varying from three times daily to once each hour. Conclusions were that the hatching rate improved from 68.3 per cent to 74.3 per cent of fertile eggs with large machines, while an improvement of about the same order was recorded with small machines. With eight turnings per day, an improvement of only 3 per cent was observed. The improvement appeared due to a decrease in embryonic mortality of the order of 1.5 per cent over the first eight days ; the remaining improvement seemed to result equally from a decrease in abnormalities and an even depression in mortality over the 8th to 21st day of incubation. The author, however, concludes that the improvement noted might not be so marked with hatching eggs of superior quality.

Further confirmation of these results are given in " On Turning Eggs during Artificial Incubation " by R. S. KALTOFEN and P. UBBELS (*ibid.*, 1953, No. 52). Other workers do not however consider that turning in excess of eight times per day leads to an effective improvement in hatching rates.

Husbandry

In Britain, dubbing of male birds is widely practised, but dubbing of large combed females is not common. In an account of " The Effect of Dubbing on Egg Production and Viability " R. K. COLE and F. B. HUTT (*Poult. Sci.*, 1954, **33**, 966-72) describe the results observed

consequent upon the dubbing of White Leghorn pullets. The wattles and combs of the dubbed birds were removed at eight weeks, and over a period of 500 days of age three eggs more than the number laid by the controls were produced. The dubbed birds excelled the controls in cold weather; with warmer weather the latter did relatively better. It is suggested that this result may be a consequence of compensatory slackening by the dubbed birds in summer, but in spite of the small total improvement, the fact that in the colder period the dubbed birds laid between six and 10 eggs more is not without economic significance in view of the present level of winter prices. Dubbing had no effect on liveability to 500 days or on body weight and age at sexual maturity.

R. C.

ENTOMOLOGY

The Biology and Control of *Otiorrhynchus Clavipes Bonsd.* (Rhyn. Colesp.), A Pest of Strawberries. A. IBBOTSON and C. A. T. EDWARDS. *Ann. App. Biol.*, 1954, **41**, 520-35.

This weevil is an important pest of strawberries, particularly in the Cheddar district of Somerset, where the work was carried out.

The adult weevils eat the foliage of the plants, though this damage is relatively unimportant; it is the severe injury caused by the larvae feeding on the roots and tunnelling into the rootstocks which is so serious.

The life history of the weevils occupies either 12 or 18 months according to whether they pass one winter as a fully grown larvae, or one winter as a small larvae and another as adult weevils waiting to emerge from the soil. They thus appear in two waves, pupating in the autumn and emerging in spring, or pupating in late spring and summer and emerging between mid-June and the end of August. The beetles lay from 100-300 eggs, both parthogenetic and fertile eggs being produced, which hatch in 17-24 days.

The young larvae burrow down into the soil as soon as they have hatched, and it is of interest that they are only able to pass through spaces in the soil which will admit their heads. The larvae feed within the root range of the plants and find their way from one plant to another by the diffusates from the roots. When mature, after five months, they pupate in earthen cells 6-8 in. below the plants.

Satisfactory methods of control have been devised. The adult weevils are easily killed with a 10 per cent DDT dust; the larvae beneath the plants may be controlled by DDT and BHC preparations poured on to the soil at the rate of 1 pint per plant. DD injection has been found to give good results and may be used when an old infested bed is to be destroyed, when the larvae can also be controlled and so prevented from spreading to younger beds nearby.

***Napomyza Lateralis* (Fall). A New Pest of Calendulas.** H. G. MORGAN. *Plant Pathology*, 1954, **3**, 85-6.

This pest is of particular interest in the south-west where the garden marigold (*Calendula officinalis*) is often grown for the cut-flower trade.

The female fly bores holes with her ovipositor in the upper surface of the leaves and lays her eggs there. The young larvae mine the leaves and move through the tissues until they strike a vein, along which they proceed to the mid rib. They continue down the petiole into the stem and often move up into the region of the primary shoot. This injury may cause a " many-neck " condition and secondary shoots may also be attacked. Severe weakening of the plants takes place and they may suffer very much from wind damage, mechanical cultivations, or the picking of the flowers. Late damage may injure the flowers or cause wilting after picking.

The larvae pupate in the stems or near the growing points. The length of the life-cycle is usually about seven weeks. There are at least three generations with much overlapping, and in sheltered parts of the south-west the fly may be almost continuously brooded. Groundsel is an important weed host. Owing to the long growing season of calendulas, which are grown as a cheap crop, full protection by spraying would hardly be practical or economic. It is suggested that the most useful period for the control of the pest is at the time of the November egg-laying, which would protect the flowers at the time when prices are likely to be highest. Sprayings with schradan, BHC or parathion have all reduced infestations.

The Apple, Pear and Quince Aphids. G. H. L. DICKER. *Ann. Rept. East Malling Res. Sta.*, 1953, 213-7.

With the increasing use of spring applications of insecticides, rather than winter egg-killing washes, and the trend towards various forms of automatic spraying machinery, minor outbreaks of aphids may become more frequent. This paper provides a simple means of identifying the common species, with the result that the risk of further injury by the various species may be more easily assessed.

Simple characters and brief biological notes are tabulated and the article should prove of great value.

L. N. S.

COMMONWEALTH AGRICULTURAL BUREAUX PUBLICATIONS

BUREAU OF PASTURES AND FIELD CROPS

Methods of Surveying and Measuring Vegetation

D. Brown, 1954, 240 pp. quarto, cloth bound; illustrated with half-tones, line drawings and tables ; index, glossary, bibliography : 35s. Part I of this book was reviewed in the winter issue of this REVIEW. Part II is written for the grassland ecologist and the pure ecologist. An analysis has been made of practically all the published methods and techniques which have been employed over the past fifty years in the quantitative study of vegetation. These methods and techniques are here synthesized under four groups or criteria : frequency, number, area covered and weight.

PROVINCIAL NOTE

THE 1953 SEA FLOOD DISASTER IN LINDSEY, LINCOLNSHIRE

J. W. Blood

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On the night of January 31, 1953, following a period of strong winds, an unusually high tide broke through the coastal defence system. At some places breaches were torn in the sea bank, and at others water spilled over the top. The sea rushed inland through the breaks like a tidal race, rapidly flooding the whole coastal belt and penetrating up to six miles inland, according to the contour of the land. In all, some 25,000 acres of land were flooded, of which 11,000 acres were grassland and 14,000 acres arable. Loss of life and damage to property was severe, and stock in the path of the onrushing water were swept away, in some cases for many miles, without a chance of survival. Stacks, potato clamps, machinery and wooden farm structures were also severely battered and, in some cases, completely dispersed.

The direct effect on the land was twofold. Close behind the breaches sand from the foreshore and sea defences was deposited in a layer of considerable thickness; near Sutton-on-Sea it reached 14 feet. Immediately beyond this area the top soil from arable fields was scoured away to be deposited in ditches or as warp on more remote land. Out of the direct path of the surging water, the land was quickly and almost gently inundated. Stock had a chance of retaining a foothold or retreating to higher ground so that fatalities were few. Produce in stack or clamp, although flooded, was not scattered, nor was the land scoured.

Immediately the impact of the disaster had passed, the more fortunate farmers rallied round to help their distressed neighbours and set about repairing the damage. Ordinary repair work they tackled efficiently, but little was known about dealing with the problems arising from the salt-water flooding of the land. Advice was urgently sought from the N.A.A.S. county staffs and, through them, from the specialist officers at Provincial Headquarters.

At this early stage, when flood water still covered much of the land, it was decided to acquaint farmers with the implications and effects of

salt-water flooding rather than to give particular advice to individuals. Consequently, lectures were quickly arranged so that the first was given by the Advisory Chemist only eight days after the disaster. All such lectures were extremely well attended and a notable feature of them was the unending spate of relevant technical questions and the complete absence of inquiries about state aid. Much assistance was given by individual farmers whose land had been flooded on previous occasions endorsing the points which were put over in the lectures and discussions.

Early in March all of the flood water had receded, and, as a result of favourable weather conditions, large areas of the lighter land had dried out. At this stage it was apparent that as much cropping as possible should take place, both to restore the confidence of the farmer and to facilitate soil improvement. As a first step, it was decided to begin sampling all arable areas to ascertain the salt content of the land. Speed was essential if this work were to be effective, so it was necessary for man-power and laboratory facilities to be augmented. District Advisory Officers from other counties in the province were deployed for the purpose of taking soil samples, and all the field officers attached to the chemistry department were stationed in the area, until sampling was completed. At the same time, two commercial firms offered to carry out gratuitous soil analyses in their own laboratories, an offer which was gratefully accepted. Samples were therefore analysed at three centres, with the interpretation of all analytical data and reporting being undertaken at Shardlow, the N.A.A.S. Provincial Headquarters. To facilitate this, valuable assistance was given by members of the administrative staff. In this first intensive sampling period, some 1,722 arable fields were covered and 4,935 soil samples taken for analysis. Sampling was always undertaken at two depths, 0.4 in. and 4-8 in., but frequently a third sample was taken at 8-12 in. About two-thirds of the samples taken were analysed at Shardlow and the remainder by the co-operating industrial laboratories.

Salt contamination of the soil was ascertained by determining the total water soluble chlorides and expressing these in terms of sodium chloride as a percentage of the dry soil. In addition, the electrical conductivity of an aqueous suspension of the soil was determined and expressed as pC. This characteristic varies with salt concentration and was carried out on the early samples as a confirmatory test. At a later stage, pC determinations, which can be accomplished very quickly, were used to differentiate between those samples which were sufficiently free from salt to require no further salinity test, and those on which a fuller analysis was required.

Soil salt concentration of these early samples was extremely variable, not only in those taken from the surface layers but also throughout the various layers examined. The limits of variation of all samples were 0.04 to 1.6 per cent salt.

When classified into groups, it became apparent that soil type had a pronounced influence on the degree of contamination. The following table gives the distribution of samples.

Table 1

Percentage of Salt	Percentage of Samples in the Various Categories							
	Sand		Light Silts		Heavy Silts and Loams		Clay	
	0-4 *in.*	4-8 *in.*	0-4 *in.*	4-8 *in.*	0-4 *in.*	4-8 *in.*	0-4 *in.*	4-8 *in.*
Below 0.1	28	22	19	10	11	7	8	6
0.1-0.24	53	50	50	33	31	22	15	13
0.25-0.75	19	28	29	48	35	45	43	42
Over 0.75	—	—	2	9	23	26	34	39

The lowest limit of contamination, 0.04 per cent salt, occurred in samples of soils from all types of texture, but the upper limit, 1.6 per cent, occurred only in samples from the heavy clays. The highest percentage of salt in samples from soils of other texture was 0.5 per cent in sand, 0.85 per cent in light silt and 1.2 per cent in heavy silts and loams.

The numbers of samples taken at 0-4 in. from land in the various texture classes were sand 114, light silt 128, heavy silt 497, and clays 920. This distribution corresponds more or less to the acreages of the various types of land flooded.

Other factors, apart from soil texture, which influenced the degree of soil salt contamination, could all be associated with drainage and previous farm management. Consolidation of the land was perhaps the most important single influencing factor. Arable land remaining in stubble, in with a one-year ley or red clover was the least affected, while land which had been deep ploughed and left rough for winter weathering was the worst affected. In between these extremes was land sown to a winter cereal or in with beans, and that prepared for early spring sowing.

A demonstration of the effect of land consolidation was shown on a number of fields sown with barley on the same day that flooding occurred. Braiding of the barley first took place in the tractor wheelings some 5-6 days before that in the rest of the field. As the crop developed, plants in the wheelings came away strongly and eventually finished normally. Those in the less consolidated land yellowed when about 4 in. high, never fully recovered and finally produced short spindly mature plants, producing a low yield of shrivelled berries. The average salt content of the 0-4 in. layer of soil in the wheelings was 0.12 per cent compared with 0.28 per cent elsewhere. In addition, penetration by the salt water was restricted by the consolidation. Salt concentration in the 4-12 in. layer of soil below the wheelings was 0.09 per cent, but in the remainder of the field it was 0.37 per cent.

The effects of land drainage on soil salt concentration were varied. Where tile drains functioned freely, salt concentration in the surface

layers of soil was always very much lower than in the subsoil. However, where water was held up in perimeter ditches because of blocked outfalls, or in cases where the ditches were silted up and preventing the field tile drains from running, the reverse was true. A similar effect occurred on land which had no artificial drainage system, especially where the ditches remained full. This latter condition was due to the concentration of sea water by surface evaporation. An exaggeration of this effect occurred on badly drained fields with raised perimeters, produced by spoil accumulation from cleaning out ditches, and on those with natural surface depressions. Ponds remained in these hollows when the flood water receded and the salt water became more and more concentrated as evaporation took place. In one such sample, the water contained 14.7 per cent sodium chloride.

By the autumn of 1953 many of the main drain outfalls to the sea had been repaired and in some cases improved so that the subsidiary ditches could be cleaned out and often deepened. Thus the land drainage system was again able to function. Tile drains ran freely, particularly on fields which had been treated with gypsum, and ponding rarely occurred. Following this, a noticeable improvement in soil structure occurred while salinity of the soil decreased more rapidly.

Effect of Flooding on the Land

As the land dried out, a hard surface crust formed with a general shrinking of the surface soil, producing a mosaic of saucer-like platelets. As drying continued, the depression in the saucers deepened and the cracks separating the platelets became wider and deeper. Below the crust the soil mainly remained glutinous. On walking the dried out land, lighter textured soils were harsh and cindery and the heavier soils gave an impression of insecurity, like walking on a jelly with a hard surface crust.

The surface platelets were difficult to re-wet and were impervious to water. Consequently, after rain, fields were quickly covered with many small puddles which coalesced after further rainfall to cause surface flooding. This phenomenon occurred irrespective of soil texture. On drying out, the same pattern was again produced on the soil surface.

After light cultivations, this hard surface crust readily broke down to a very fine tilth which, after rain and re-drying, again produced a crust. The production of such an excellent tilth by cultivations often tempted farmers to proceed with normal farm management despite contrary advice from specialists. Because of the creation of a sense of false security, this tilth became known as a " Devil's Tilth ".

As long as any salt remained in the soil, the dried crust would always produce a devil's tilth after cultivations. However, as soon as the soil salt concentration fell below 0.02 per cent, cultivations failed to produce a tilth and, under certain conditions, the soil began to segregate into various particle-sized fractions. An application of gypsum prevented this separation, except where the soil was left in ridges, noticeably on ploughed land left in seam. In these latter cases, fine silt and clay was

washed into the furrows, leaving coarse sand on the peaks of the ridges and intermediate-sized fractions on the face of the seam. Where this happened water accumulated in the furrows, but this condition could be remedied and further breakdown of the soil allayed by harrowing down the ridges.

Effect of Flooding on Crops

Observations on the effect of flooding on crops in the first year fell into three categories: those which were already planted, those planted on the advice of the Advisory Service after the flood and those planted for experimental assay.

CATEGORY I

All crops in the first category suffered a setback, but the degree of damage depended on the ultimate percentage of salt in the soil, the length of time the flood water remained on the land, whether the crop was in the path of rushing flood water and the subsequent extent of manurial treatment. Symptoms and reaction of some crops are listed below.

Cereals. In all circumstances a general yellowing of foliage and complete killing of the seminal root occurred. Where the crop was in the path of rushing water, the aerial part of the plant was embedded in the soil where it eventually rotted. Partial recovery occasionally occurred on light sands. Many crops were drowned where flood water remained on the land longer than eight days, but where crops persisted they survived as chlorotic seedlings until a secondary coronary root system was produced after three to four weeks and the plant began to revive. When the soil dried out, these secondary roots quickly browned at the tips and the crop received another set back. Following wet weather, which fortunately generally prevailed, the new root system recovered and the plants made chequered headway. In the majority of cases the whole root system developed in the top 1-2 in. of soil only. In this layer, the soil salt content was always relatively low due to continuous wet weather, but frequently below this level the salt content was high, on occasions up to 0.6 per cent. General chlorosis persisted until nitrogen was applied. Provided repeated dressings were given, crops gave a fair yield, varying from 10-30 cwt. grain per acre, the higher yields being derived from the lighter soils where the salt was more rapidly leached out.

Tares. All were rapidly and completely killed out, irrespective of conditions.

Beans. This crop was very susceptible to salt poisoning. First the root system blackened and ultimately shrivelled to a thin, hard black strand. The older leaves then showed black marginal necrosis, a condition which eventually spread over the whole plant.

On higher ground which projected slightly above flood water, the root system was blackened and killed only to the level of the external water. Some black marginal necrosis occurred on the foliage, but eventually the plant developed a secondary root system in the non-flooded soil and partly recovered to give a dwarfed plant which failed to fructify.

Red Clover and Lucerne. Red Clover and Lucerne stands were showing vigorous young growth when the flood occurred. After flooding, clover foliage assumed a russet brown, and lucerne a pale brown, marginal necrosis. In both crops all the existing foliage died, crowns and tap roots of the plants wizened, rootlets became discoloured and often died.

On light sands and silts, irrespective of salt content, recovery was fairly rapid with secondary growth appearing about a fortnight after flooding and tap roots becoming normal after about 12 weeks. Yields were about 50 per cent of normal. On heavy land mortality of red clover plants was high, even at the 0.35 per cent soil salt content, and ultimate yields were low. Lucerne produced a fair stand even when salinity reached the 0.7 per cent level.

Soft Fruits. The effect of flooding on soft fruit bushes was very varied. In some plantations a complete kill of some bushes occurred while others, under identical conditions, survived. There was, however, a general gradation of tolerance in the various varieties of fruit; raspberries were the most severely affected, followed by gooseberries and red currants with black currants being relatively tolerant. All surviving bushes came into leaf, which rapidly assumed a brown marginal necrosis resulting in premature leaf fall. In severe cases very rapid defoliation took place followed by a further crop of leaves which again became necrotic. Gooseberries and currants generally produced some fruit even where complete defoliation of the bushes took place. In 1954, surviving bushes grew normally but fruiting was severely restricted and of poor quality.

Hard Fruits. At first these appeared to be unaffected, coming into leaf and flower normally. Later, brown or black necrotic blotches occurred on the leaves and there was a fair amount of premature leaf fall. Fruiting was extremely light with small and frequently misshapen fruit. In many instances trees blossomed a second time in late summer. Later the topmost branches of older trees sited on the higher contaminated soils died, while younger trees were completely killed. Apples were more severely affected than pears, but Bramley's Seedling appeared to be relatively tolerant. As with the soft fruit, there were trees completely dying *juxta* those showing little damage. All fruit in 1953 was extremely sour when ripe and quality was also poor in the 1954 crop.

Bulbs. All bulbs were killed where the soil salt content was above 0.3 per cent. At about this limit, misshapen and dwarfed leaves of normal colouring were produced and the flowers were small on very short stems, sometimes only about one inch long. The lower the salt content, the more normal were the leaves and flowers.

Grassland. The effect on grassland was varied. In some cases flooded fields appeared to be as productive as formerly, but generally spring growth was slower and not relished by stock. Clovers and the better grass species were greatly retarded in growth and, after prolonged flooding, were often killed. As the season progressed growth and palatability improved. It was noticeable that where management and fertilizer treatment had been good before and after flooding, grass growth was good. Stocking of grassland was often very difficult because of contaminated water supplies with a consequence that much of the grass was cut for hay.

CATEGORY II

In the second category, barley, seeds and ryegrass were the main crops recommended in 1953, but occasionally onions, beet and brassicae were advised in special circumstances.

Barley. All crops germinated well, although germination was delayed in soils of higher salt contamination. Except on the lighter soils, rate of growth was sporadic and in all cases gave the impression of nitrogen deficiency. Top dressing with " Nitro-Chalk " temporarily cured the symptoms and restarted growth. Repeated applications were invariably needed. Generally 6-8 cwt. of " Nitro-Chalk " per acre were applied throughout the season, but instances where 12 cwt. per acre was used were not uncommon. Yields varied between 10 and 28 cwt. per acre.

Grasses. Those grasses sown during spells of dry weather germinated and grew away well, eventually producing a fair crop. When rain followed drilling the surface soil caked and, although normal germination of the seed occurred, seedlings could not emerge through the hard surface layer. Emergence took place only through the cracks in the surface crust, and consequently, most of the crops grown under these circumstances were a failure. After gypsum was spread no difficulty arose and fair to good stands of grass were obtained.

CATEGORY III

In the last category were experiments carried out by the Crop Husbandry Department to ascertain the tolerance of most farm crops to salt. On these sites a small number of rows of individual crops and strains of the same crop were sown with adequate fertilizer treatment. The following sequence in descending order of salt tolerance was noted : fodder beet, Italian ryegrass, giant rape, barley (certain varieties), oats (certain varieties), perennial ryegrass, Marrowstem kale, timothy, cocksfoot, red fescue and clover (all varieties).

Advice to Farmers

The first direct advice to farmers on cropping and soil treatment was made after the intensive soil sampling campaign in March 1953. By mutual agreement between the County Agricultural Officer and the Provincial Chemist, recommendations were made by the chemist. These were based solely on the analyses of soil samples and were included in the chemist's report. The reports were directed to the various district officers, who in turn delivered each one personally to the farmer concerned and discussed its implications with him. This personal contact was a very important factor in the restoration of flooded land.

Analytical data were classified according to the salt concentration of the 0.4 in. and 4-8 in. layers of soil. Where the classifications were very low in both layers of soil, farmers were allowed to sow whatever crop they wished. If this condition pertained to sand land or very light silt land, no restrictions were made on cultivations. Where, however, the land was heavier, cultivations were restricted to discing or harrowing. When salt concentrations in the soil lay between 0.08 per cent and 0.2 per cent, cropping was restricted, with an emphasis on barley. In all such cases cultivation of the land was restricted to light harrowing or discing. When soil salinity lay between 0.2 per cent and 0.4 per cent, it was suggested that seeds might be sown but that a risk would be involved towards the upper limit and ryegrass would then be a better alternative. On all land with a salt concentration higher than 0.4 per cent, a no-cropping policy was advised. It was suggested that light cultivations should be made periodically, when conditions were ideal, to restrict the growth of weeds.

Manuring of crops was restricted to treatment with superphosphates and " Nitro-Chalk." Wherever possible, it was suggested that crops should be combine drilled with ordinary superphosphates so that the gypsum contained in it would facilitate seedling emergence. It should

be remembered that this advice was given before land had been treated with gypsum. A seed bed application of 2 cwt. "Nitro-Chalk" per acre was always advised but subsequent top dressings were left to the discretion of the farmer.

In the autumn of 1953, a second intensive soil sampling campaign was instigated with a result that more extensive cropping was advised for 1954. The following table shows the extent of this change, the first part giving acreage and the second percentage distribution of the various crops.

Table 2

	1953	1954
Acreage cropped	8,860	13,200
Acreage uncropped	4,718	400
	per cent	*per cent*
Cereals	32	66
Seeds	14	18
Grass	15	7
No cropping	39	3
Potatoes, roots, peas, etc. ...	—	6

SECOND INTENSIVE SOIL SAMPLING

During this period samples were taken in the 0-6 in. top soil layer only. Salt contamination had considerably diminished, undoubtedly due to the continuous wet spells experienced during the spring and summer. The following table gives the distribution of the samples classified into various categories of salt content :

Table 3

Percentage of Samples in the Various Categories Sampled at 0-6 in.

Salt Percentage	Sand	Light Silts	Heavy Silts and Loams	Clay
Below 0.1	65	52	35	28
0.1-0.24	30	28	38	42
0.25-0.75	5	20	27	29
Over 0.75	—	—	—	

Compared with the results from the first intensive sampling, there was an extensive shift in the incidence of salt contamination. For this reason, and because of indications that a decline would continue, cropping and soil treatment was recommended which would not have been given earlier. Wherever gypsum had been applied and the salt content did not exceed 0.25 per cent, farmers were advised to shallow-plough their land in preparation for winter sowing.

Treatment of Land with Gypsum

In the early summer of 1953, a supply of gypsum was made available to farmers for application to all arable land with a salt content of 0.1 per cent and over. Two types were supplied : finely ground mineral gypsum for application at the rate of 2 tons per acre and by-product gypsum from the manufacture of fertilizers at 50 cwt. per acre.

The gypsum was mainly spread by contractors using lime-spreading equipment. By-product gypsum appeared to spread more evenly than the ground mineral and had the added advantage of containing small quantities of phosphates. In some samples, the equivalent of 5 cwt. superphosphates was applied with each 50 cwt. dressing of by-product.

Further supplies of gypsum were made available for application during 1954 and others will be made this year.

The effect of the gypsum on all types of soil was dramatic. Caking of the upper surface of the land was prevented, and drainage was immediately improved. Ponding, which had hitherto occurred on most of the land following rain, never occurred after gypsum had been applied. All the early deliveries in 1953 were usually applied to bare land. Since cultivation of all bare ground had been recommended to prevent weed growth, the gypsum was inevitably mixed with the top inch or so of soil. In some cases where cultivations had been neglected, weed infestation had become serious, both before and after gypsum had been applied. On this land weeds were eradicated by rotary cultivation, so that the gypsum was intimately mixed with the top 2 or 3 inches of the soil. Observations indicated that where the gypsum was cultivated into the land by rotary equipment the resulting conditions were much better than those achieved with any other mode of treatment.

Experience has shown that heavier initial dressings of gypsum than the 2 ton allocation enhanced the beneficial effect on soil structure and drainage. Generally the recommended dressing affected only the top 2-3 in. of the soil in the year of application, but the heavier dressings influenced a correspondingly deeper layer.

Experiments

Immediately the flood water subsided, ten experimental sites on varying soil types were selected for ascertaining the movement of chlorides on the land.

Samples were also taken from these sites at intervals to investigate the bacterial fauna. Investigators had mobile laboratory facilities so as to make their preliminary inoculations and cultures from the fresh soil.

Some of the sites were under crops and others were on bare land which remained so for the next eighteen months. Each site was confined to an area of 2 yards square and for salt determinations sampling has been carried out at four-weekly periods from the middle of February 1953 onwards. The soil was sampled at 0-6 in., 6-12 in., 12-18 in. and 18-24 in. Statistical analysis of the accumulated data brought out the following points :

> Salt is eliminated from bare land more readily than from cropped land and this factor appears more limiting than soil texture.
>
> On bare land there was little difference in the concentration of salt in the various layers of the lighter soils, but on the heavier soils it was highest in the 6-12 in. layers, decreasing progressively down to the 24 in. level. This seems to indicate that penetration by sea water was uniform in the lighter soils but was impeded in the heavy soils.

At some time during the summer the average salt content of the soil down to 24 in. increased, a feature which could be tied to rainfall.

The highest concentration of salt in the lighter soils occurred at the end of April, 1953, but on the heavier soils it occurred at the end of May.

A regression equation for the correlation between salt content and rainfall showed that unless 0.9 in. of rain fell during 14 days the salt content of the soils would not be reduced.

Following heavy rainfall, there was an immediate lowering of the percentage of salt in uncropped soils, irrespective of texture, but there was approximately 14 days delay between the rain and the fall in salt concentration on the cropped soils.

On cropped land, both light and heavy soils had the highest salt concentrations in the surface layers with a progressive decrease down to 24 in.

In light soils, salt concentration was negligible in the 0-12 in. layer by June 1954 and down to the 24 in. level by October, 1954. On heavy land negligible amounts in the 0-12 in. layer occurred during October, 1954, but approximately 0.1 per cent salt still remains in the 12-24 in. layer.

Towards the end of 1953 some 3.8 ac. of medium-heavy silt land were taken on a long lease for carrying out detailed experiments on the effect of management on the restoration of sea-flooded land. Various types of cultivations, with and without gypsum applications, have been undertaken and a varied crop rotation used to measure the effects. Observations made during 1954, indicated that the mode of cultivation carried out in the autumn had no effect on crop yield, but ploughing in the spring, compared with other forms of cultivation, depressed the yield of spring sown crops. Rotary cultivations, with or without gypsum, had the greatest beneficial effect on soil texture. Wherever gypsum was applied, soil structure was improved but this improvement was not reflected in increased crop yields, except where land had been spring ploughed.

In conclusion, evidence suggests that the advice given, although it accomplished excellent results and was well accepted, was too cautious. These results may have been due entirely to favourable weather conditions and had dry weather followed flooding an entirely different position could have resulted. Possibly, therefore, greater liberties in cropping recommendations might be taken should another similar disaster occur.

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Appendix

Note : Parts I to V of this Report constitute the Report of Proceedings under the Diseases of Animals Acts.

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